

PERIOD PRECEDING HEADING

Evaporation:	
45 to 50 days preceding heading.....	— 374
40 to 45 days preceding heading.....	— 449
35 to 45 days preceding heading.....	— 508
20 to 30 days preceding heading.....	— 446
Temperature:	
Average temperature 20 to 30 days preceding heading.....	— 316
Maximum temperature 15 to 25 days preceding heading.....	— 436
Humidity (for 10 years only):	
25 to 30 days preceding heading.....	+ 368
5 to 25 days preceding heading.....	+ 117
AFTER HEADING	
Average temperature for 10 days after heading.....	— 250
GENERAL	
Rainfall planting to ripening +40 percent of fallow year....	+ 247
Rainfall planting to heading +40 percent of fallow year....	+ 274
Rainfall fallow year.....	+ 327
Rainfall of calendar year.....	+ 113
Rainfall planting to ripening.....	+ 457
Number of days from emergence to heading.....	— 133
September and October rain.....	— 317

TABLE 2.—Crop yields and weather data ¹

Date	Yield	1	2	3	4	5	6	7	8	9
1909.....	11.1	9	24	16.7	70.9	3.06	1.005	0.16	69.5	0.33
1910.....	15.8	4	27	17.9	74	1.21	1.286	T	73.4	.51
1911.....	21.4	4	44	17.0	61.1	.84	1.382	0	68.8	.17
1912.....	17.1	9	24	16.8	66	2.69	1.375	.55	70.8	.72
1913.....	5.4	7	30	18.3	74.65	1.63	1.503	.02	84.3	.46
1914.....	42.7	16	12	11.1	66.7	5.70	.679	.34	71	2.26
1915.....	34.2	15	24	17.2	68.77	5.75	.794	.18	66.8	1.04
1916.....	14.6	3	34	20.5	68.05	1.24	1.049	0	63.6	.00
1917.....	26.1	13	17	12.2	60.55	5.12	.467	.45	56	1.73
1918.....	16.4	6	34	15.1	69.05	1.91	1.226	0	68.8	.06
1919.....	20.6	7	21	13.8	68.05	1.70	.977	.14	70.4	.91
1920.....	24.4	11	25	12.7	64.09	3.81	.955	.53	70.6	.55
1921.....	35.4	12	11	10.8	64.7	4.80	.712	.84	60.2	1.72
1922.....	13.6	5	37	18.0	68.3	2.28	1.319	0	77	.00
1923.....	21.8	11	18	14.7	66.8	3.31	.701	.28	64	.94
1924.....	19.3	5	55	14.5	68.4	1.91	1.435	0	80.5	1.84
1925.....	30.3	8	19	14.1	65.92	3.60	1.174	0	74.6	1.39
1926.....	39.4	9	26	0.4	66.8	3.43	.535	1.58	59.4	1.65
1927.....	15.7	7	33	16.1	68.8	2.14	.977	.01	70.4	.26
1928.....	25.6	9	14	12.1	67.6	2.29	.732	1.03	65.2	1.52
1929.....	19.7	9	27	15.0	67.8	2.92	.941	.29	68.4	1.51
1930.....	19.0	9	20	11.7	68.2	3.23	.321	.11	56.2	.30
1931.....	23.7	6	17	13.8	70.9	1.70	1.232	0	79.2	.50
1932.....	18.9	7	21	14.2	68.78	1.61	1.194	.50	73	1.58
1933.....	19.2	12	27	13.5	62.50	3.98	1.279	.08	68.6	.11

¹ Figures in column 1 show number of days with .10 inch of rainfall from April 1st to Heading, 2 Severity of drought (number of days in longest rainless period) etc. See arabic numbers in Figure 1, for other titles.

FLOODS IN THE SACRAMENTO VALLEY, FEBRUARY 27–MARCH 6, 1940

By E. H. FLETCHER

[Weather Bureau, Sacramento, Calif., May 1940]

The flood that occurred in the Sacramento Valley late in February may well be classified as one of first magnitude, exceeding that of December 1937, and in some respects surpassing any flood since systematic records have been kept by the Weather Bureau. From Kennett, Calif., to the mouth of the Feather River, new all-time high water marks were established generally.

The rainfall season of 1939–40 did not get under way until near the end of December. However, during January and most of February frequent rains over the Sacramento River system kept the streams and bypasses at high, but not flood levels.

Near the beginning of the year the California-Hawaiian high-pressure system had receded far southward of its normal winter position, and was replaced by storm areas of much greater intensity than ordinarily appear in that region. Consequently, a succession of slow-moving cyclonic disturbances, advanced northeastward off the Pacific coast, with intermittent warm-type occluded cyclonic systems moving inland over northern California, and causing precipitation in the form of rain at much higher elevations in the mountains than is usual during the midwinter months. This situation accounts for the marked deficiency in snowfall that prevailed until late in the season.

On February 24–25, the last one of this series of northeastward-moving storms apparently caused the importation of a large volume of semi-tropical air near the California coast, whence it was carried inland on February 27–28 by another and more intense storm of the Aleutian type with exceptional frontal activity, producing torrential rainfall in the Sacramento drainage area. On the morning of the 29th, a cold front had advanced inland over the Pacific northwest, bringing lower temperature and snow to the mountains, with clearing weather following. Thus ended a cycle of storms that was directly responsible for the disastrous flood of February.

The excessive rainfall was mostly confined to the 5-day period, February 25–29, with the most intensive fall occurring on the 27th–28th. However, the antecedent rainfall extending over a period of about 2 months, was a highly

important contributing factor to the flood-producing run-off.

It was apparent as early as Monday morning, February 26, that a period of high water was inevitable, and the river bulletin that morning contained the following general forecast: "A general rise is developing in all streams, and with continued heavy rains in prospect, high stages will result in the Sacramento River and probably the lower San Joaquin, during the next 2 or 3 days."

During that day a close check was maintained on the situation by means of hourly weather reports that were received by teletype. At 5 p. m., when the river stage at Red Bluff (flood stage 23 feet) was only about 13 feet, flood warnings were issued for that vicinity and Tehama County.

The upper courses of all streams in the Sacramento drainage area began to rise rapidly during that night, and on the morning of the 27th, flood warnings were repeated, stressing that the serious conditions that were rapidly developing would be intensified during the next 24 hours by expected additional heavy rainfall, and that extremely critical flood conditions, equaling or exceeding those of December 1937, would prevail in the Sacramento Valley during the next 3 days.

Warnings were also issued to the effect that mild flood conditions would be experienced in the lower reaches of the eastern tributaries of the lower San Joaquin River, namely, the Consumnes, Mokelumne, Calaveras and Stanislaus Rivers.

From the influence of the American River, the Sacramento River at Sacramento rose steadily on the 27th, and at 10:30 p. m., when the stage was 28.5 feet, the 48 gates of the Sacramento Weir, 3 miles upstream from the City, were opened, permitting the excess water to escape westward into the wide expanse of the Yolo Bypass, which conducts the water southward to the vicinity of Rio Vista, where it reenters the broad river channel.

After the weir gates were opened the river at Sacramento fell during the next 5 hours to 26.5 feet and remained practically stationary for several days. The city of Sacramento was at no time endangered.

As soon as it was known that the Sacramento Weir gates would be opened, thus diverting a large volume of the Sacramento River flow into the bypass, warnings were distributed to all those having interests in and adjacent to the lower Yolo Bypass, informing them that the water level in that basin within the next 48 hours would rise rapidly, and the so-called tidal reclamation tracts would be flooded.

At the beginning of the flood period there was very little snow below the 5,000-foot elevation in the Sierra Nevada mountains. Above 6,000 feet, rain and snow fell intermittently at first, but turned to snow later at the higher elevations. While there was some water released by the complete melting of from 12 to 15 inches of snow in the vicinity of the 5,500-foot level, it was not so important as compared with the effect of the unrestricted run-off from rainfall below 6,000 feet, due to absence of the normal snow pack.

Because of the northward movement of the main storm center off the Oregon coast, the region of high-intensity rainfall was confined to the upper half of the Sacramento River drainage basin, including the headwater areas of the Feather River, Putah, Cache, and Stony Creeks.

Following 4 days of torrential rains, centered in the Sacramento River canyon, the river at Kennett crested on the morning of February 28, at the momentous stage of 36.3 feet, which is 3.1 feet higher than the previous high record in 1907, and 7.3 feet higher than in December 1937. By 5 p. m. of the 28th, the flood crest had reached Red Bluff with a stage of 32.2 feet, which is 9.2 feet above the flood stage and 0.2 foot above the previous high-water mark which was established in 1937. Table 1 shows the crest stages reached at various points along the Sacramento and tributaries as well as comparative data.

TABLE 1.—Crest stages and comparative data, high water, February–March 1940

Station and river	Crest stage	Time and date	Departure from flood stage	High stages previous floods	
				Prior to December 1937	December 1937
<i>Sacramento River</i>					
Kennett.....	36.3	9 a. m. Feb. 28.....	+11.3	33.2, March 1907.....	29.0
Red Bluff.....	32.22	5 p. m. Feb. 28.....	+9.2	30.5, February 1909.....	32.0
Hamilton City.....	22.64	4 p. m. Feb. 28.....	+2.6	20.6, March 1928.....	22.8
Ord Ferry.....	121.6	7 p. m. Feb. 28.....	—	—	121.0
Colusa.....	29.5	6:30 a. m. Mar. 1.....	+1.5	29.3, March 1907.....	26.8
Knights Landing.....	34.05	8 a. m. Mar. 1.....	+4.0	32.2, March 1907.....	32.6
Sacramento.....	28.5	11:10 p. m. Feb. 27.....	— .5	29.6, January 1909.....	27.7
<i>Feather River</i>					
Oroville.....	25.1	12:01 a. m. Feb. 28.....	+1	28.2, March 1907.....	26.3
Nicolaus.....	26.3	6 p. m. Feb. 29.....	+1.3	23.2, March 1928.....	24.6
<i>Yuba River</i>					
Colgate.....	14.8	9:35 a. m. Feb. 27.....	—	23.4, March 1928.....	22.0
Secondary crest.....	14.8	12:30 a. m. Feb. 28.....	—	—	—
Marysville.....	25.0	11 p. m. Feb. 28.....	—3.0	24.0, March 1928.....	25.7
<i>American River</i>					
Folsom.....	19.1	1 a. m. Feb. 28.....	—	26.8, March 1907.....	23.9
H Street Bridge.....	39.2	4 a. m. Feb. 28.....	— .8	—	—
<i>Stony Creek</i>					
St. John.....	13.9	2:30 p. m. Feb. 28.....	+1.9	13.2, March 1907.....	12.0
<i>Mokelumne River</i>					
Bensons Ferry.....	13.3	7 a. m. Feb. 29.....	+1.3	14.3, February 1936.....	14.4
<i>San Joaquin River</i>					
Lathrop.....	14.4	11 a. m. Mar. 2.....	—2.6	22.5, February 1911.....	5.2
<i>Yolo Bypass</i>					
Lisbon.....	22.8	9 a. m. Mar. 1.....	—	—	—
Liberty Is. Farms.....	17.97	10 a. m. Mar. 1.....	—	—	—

Intensive rainfall was centered in the Sacramento River canyon area above the Shasta Dam construction site. At Kennett 12.51 inches of rain fell in 2 days. Other high 48-hour amounts are: Hobergs, Lake County, 16.55 inches; and Stirling City, on the West Branch of the Feather River, 15.20 inches. The greatest 5-day rainfall, 20.15 inches, also occurred at Stirling City. Table 2 shows the daily rainfall during the storm period for most of the mountain stations in this river district.

TABLE 2.—Rainfall from Feb. 22 to Mar. 2, 1940, inclusive (inches)

Stations	Eleva- tion, feet	February								March			Total
		22	23	24	25	26	27	28	29	1	2		
Sacramento River													
Mineral	4,950	.20	.10	.20	.90	1.90	.30	2.40	.30	0	0	6.30	
Mount Shasta	3,555	.09	T	.27	.42	.72	2.20	3.50	.38	T	.25	7.83	
McCloud	3,270	.02	.07	1.37	1.06	2.86	4.18	1.45	0	.33	0	11.34	
Hobergs	2,980	0	0	.05	.50	1.15	8.42	8.13	1.39	.06	0	19.70	
Kilaro P. H.	2,642	.16	.24	.33	.49	.49	1.73	1.95	.59	0	.50	6.47	
Dunsmuir	2,300	.17	T	.61	2.32	1.37	3.61	4.15	1.10	0	.34	13.67	
Montgomery Creek	2,145	.17	.41	.36	.81	.62	3.62	4.20	.58	.38	0	11.15	
Volta P. H.	2,100	.25	.04	.11	.24	.65	1.22	1.42	.39	0	.32	4.64	
Clear Lake	1,350	0	0	.04	.16	1.37	2.42	2.78	.34	0	0	7.11	
Vollmers	1,332	.07	.10	1.31	.51	4.70	3.92	3.56	0	.38	0	14.55	
Beegum	1,291	0	0	0	.06	.83	1.60	2.30	.03	0	.05	4.92	
Stonyford	1,205	0	0	0	.28	.32	2.44	2.97	.12	0	0	6.13	
Middletown	1,105	0	0	0	.42	.53	6.48	4.25	1.30	0	.05	13.03	
Squaw Creek	900	.09	.05	.40	1.50	.93	5.08	5.32	1.75	0	.40	15.52	
Stony Gorge Reservoir	800	.02	.07	.10	.25	.81	1.70	2.21	.11	0	.01	5.28	
Paskenta	740	.04	0	0	.27	.14	1.67	3.02	0	0	0	5.14	
Redding	718	T	.03	.58	.36	3.68	3.28	1.02	T	.26	0	9.21	
Kennett	655	.10	.01	.05	1.12	.70	5.41	7.10	.23	0	.23	14.95	
Sacramento	25	.01	.06	T	.88	1.46	2.19	1.01	.02	0	0	5.63	
Feather River													
Bucks Storage Reservoir	5,070	T	.39	.12	.90	3.05	7.42	4.88	1.09	0	T	17.85	
Canyon Dam	4,570	.02	.06	.20	.91	1.98	4.27	3.12	.79	0	.04	11.39	
Stirling City	3,525	T	T	.08	1.15	1.71	8.49	6.71	2.01	.02	.32	20.49	
Brush Creek	3,500	0	0	.14	1.02	1.24	7.24	5.15	1.68	.03	.19	16.69	
Quincy	3,409	0	T	T	.40	1.87	4.48	3.31	1.10	0	.03	11.19	
West Branch	3,216	.03	.01	.07	1.62	3.45	0.73	4.64	1.49	0	0	18.04	
Feather Falls	2,973	0	0	.95	1.24	5.50	3.78	1.22	0	.09	.30	13.08	
De Sable	2,700	T	T	.02	1.50	3.50	7.00	3.58	1.62	0	.25	17.47	
Challenge	2,700	0	.20	0	1.67	3.57	5.33	2.50	1.30	.15	0	14.72	
Bucks Creek	1,750	.02	0	.14	1.00	2.20	5.70	4.45	1.92	0	.30	15.73	
Las Plumas	569	0	0	.01	1.07	3.13	7.66	2.11	1.13	0	.10	15.21	
Oreville	273	0	0	0	.45	.55	2.45	1.85	.33	0	T	5.63	
Yuba-Bear River													
Bowman Dam	5,347	T	1.15	.27	1.75	2.09	4.28	2.42	1.91	T	.36	14.23	
Lake Spaulding	5,070	.06	1.42	.24	1.42	1.92	5.60	2.37	2.40	T	.21	15.64	
Scales	4,300	0	.38	0	1.60	2.65	6.75	3.60	2.42	0	0	17.40	
Deer Creek	3,700	.01	1.12	.06	1.48	2.16	5.41	2.93	2.71	0	.20	16.08	
North Bloomfield	3,100	0	.32	.42	.75	.85	5.27	3.65	2.45	.27	.31	14.29	
Downville	2,890	0	.29	.55	1.09	.64	6.71	4.59	2.95	.37	.16	17.35	
Camptonville	2,850	.12	.39	.12	1.83	2.64	2.73	2.33	.75	.10	.14	11.15	
Nevada City	2,570	0	.25	.35	.91	1.05	4.44	3.15	2.36	0	.12	12.63	
Chute Camp	1,358	0	.25	.08	1.85	1.96	3.05	1.46	1.40	.21	0	10.26	
Colgate	582	0	.08	.67	1.59	2.66	1.92	1.06	0	.14	.14	8.12	
American River													
Twin Lakes	7,920	.12	1.20	0	T	.50	3.64	1.89	.70	0	T	8.05	
Soda Springs	6,752	0	.76	.48	.38	.62	3.00	2.75	1.13	.07	.13	9.32	
Blue Canyon	4,750	.16	.84	.97	.73	1.25	3.72	2.83	1.90	.21	.31	12.92	
Riverton	3,230	0	1.10	.07	.33	.51	2.72	2.21	1.73	T	0	8.67	
Gold Run	3,227	0	.43	.73	.11	1.53	3.58	2.96	2.85	.34	.27	12.80	
Iowa Hill	2,970	0	.75	0	.96	.67	3.53	2.30	1.64	.15	.20	10.20	
Colfax	2,421	0	.62	.59	.32	1.05	2.46	2.95	1.96	0	0	9.95	
Georgetown	2,300	.41	1.55	0	1.33	1.85	2.45	2.03	1.02	.40	0	11.04	
Foresthill	2,200	0	.88	.75	.95	.90	3.40	2.25	2.00	.20	.13	11.46	
Placerville	1,925	.23	1.13	0	.47	1.21	3.73	1.05	1.08	0	.11	9.01	
El Dorado P. H.	1,887	.16	1.85	.03	.55	.93	4.43	1.46	1.25	0	0	10.66	
Folsom	252	0	.26	.03	.52	.75	2.01	1.47	.58	0	0	5.62	
Cosumnes River													
Fiddletown	2,100	.33	.84	0	.37	1.38	1.54	1.05	.58	.05	.05	6.17	
Big Canyon Mine	850	0	0	0	0	2.09	1.43	.95	1.29	.12	.12	5.88	
Calaveras River													
San Andreas	996	0	.50	.46	.16	.35	2.11	1.50	.89	.05	.01	6.03	
Tuolumne River													
Hetch Hetchy	3,530	T	1.28	.92	.03	.72	1.34	.63	1.14	.06	0	6.12	
Sonora	1,825	.38	1.32	0	.38	.29	2.98	.52	.54	0	.02	6.44	

In contrast to the meteorological conditions that immediately preceded the 1937 flood, when an extensive over-running semitropical Pacific air mass aloft caused almost

unprecedented excessive rains to reach the Sierra summit with dashing run-off in headwater areas, the recent storm by comparison was not so intense at high elevations, although the period of effective rainfall this year embraced about 7 days, as compared with about 3 days in 1937.

While the rainfall in the February storm was excessive, it was not of the heavy cloudburst type generally in the higher mountains, as was characteristic in 1937. Consequently, the streams, although substantially higher this year, did not rise with such great rapidity, but the high flow in the river was sustained for several days longer this year, a condition that was especially damaging to levees, particularly on March 1, when accompanied by strong north winds that induced destructive wave action.

The development of this flood in record proportions resulted largely from the fact that the requisite conditions necessary for high water were being built up over a period of 2 months. From continued rains the soil was thoroughly saturated and in a condition for a high percentage of run-off over a watershed with a comparatively high snow line. Also the streams and bypasses were already carrying large volumes of water. Preceding the 1937 flood, some of these factors were not so highly developed.

Some of the remarkable features of the recent flood were: (1) Notwithstanding the unparalleled high water in the upper Sacramento River, Stony Creek with even greater abnormality, caused the Sacramento River from Hamilton City to Butte City to crest in advance of the upstream peak flow. (2) Immediately following the break in the levee on the Sutter and Tisdale Bypasses, the water level in the river and bypasses fell rapidly downstream, reaching the Delta region within a few hours, whereas the usual time interval is about 2 days. (3) Another feature was the long flood wave that was in progress from Kennett to the mouth of the Feather River on February 28, forming an unbroken wall of flood water for about 250 miles.

It is believed that adequate and timely warnings were issued by the Weather Bureau when early in the storm's development warnings were issued to the effect that conditions would equal or exceed the 1937 flood. These warnings were consequently of inestimable value to farmers, stockmen, reclamation district officials, engineers, Red Cross officials, and others affected by the water situation; as all interests knew what to expect, because memories of the 1937 flood were still in mind.

The extraordinary vigilance that was maintained by supervising engineers and reclamation officials throughout the valley in safeguarding levees that were severely strained, and in repairing hundreds of minor breaks, was instrumental, no doubt, in preventing wholesale disaster in many areas. For example, the Sutter Basin with a 60-mile levee system, was saved only by desperate efforts.

The magnitude of this flood in the upper Sacramento Valley can be realized by considering that it is the greatest for a period of about 40 years, or since authentic records have been kept. However, farther down the river, where the flood-control system with its bypasses and levee-construction work has been constantly changing conditions, the present river-gage heights are not comparable with those of earlier years and consequently are not a true index to the volume of water that is being discharged by the system. Yet it is true that the gage readings are representative of the danger present and indicate the responsibility of the Weather Bureau in issuing adequate warnings.

Before there was any flood-control system in operation in the Sacramento Valley, the overflow waters drained into natural basins of unreclaimed land on each side of the river. Under present conditions where the water is con-

fined to leveed channels, gage heights are not only proportionately higher for the same volume of water, but failures in levees are more disastrous because more reclaimed lands are affected. This, in a general way, explains why the Weather Bureau, being primarily concerned with floods, uses the river gage height as a measure of flood danger instead of the flow in second-feet. In this connection it may also be explained that the gage height representing the "flood stage" that is assigned to a station on a leveed stream represents the "danger stage" rather than overflow stage.

Overflow due to the high water was extensive. Some of the major inundations and the acreage affected are as follows:

East of Hamilton City 60,000 acres were under water. This was considerably more than in 1937 although the crest at Hamilton City was 0.2 foot lower than in 1937.

During the early morning of the 29th, numerous levee failures in the Butte City-Princeton area caused increasing overflow on both sides of the river. On the east side, the combined overflow waters from the river and from Butte and other creeks, en route to Sutter Bypass, covered an area of about 145,000 acres in the Butte Basin, which contained mostly grain land. On the west side of the river, water escaped from a dozen breaks between Ord Ferry and Princeton and covered about 120,000 acres of reclaimed land in the Colusa trough area.

At the peak of the flood wave, on the early morning of March 1, failure of the levee on Sutter Bypass, east of Meridian and on the north side of Tisdale Bypass, caused inundation of 37,000 acres of highly valuable farm land.

In the Yolo Bypass and the adjacent Delta region, the total acreage of the five principal island tracts flooded was approximately 30,000.

In addition to the flooding of farm lands, the outskirts of many towns in the central valley were flooded and were more or less isolated for a period of time because highways and railroads became impassable and wire and power lines were decommissioned.

All persons in the inundated areas were generally warned in advance to evacuate the danger zones. There were some cases in farm districts where families were marooned in houses by the sudden breaking of levees, but these persons were rescued in boats by the Red Cross and other workers. According to records of the American Red Cross no persons were injured but two lives were lost.

A very special effort was made to secure reliable statistics of losses sustained by reason of the flood. The tabulation below is the result of questionnaires returned from authentic sources of information. Judgment was exercised to exclude any overlapping estimates in reports from different sources. The items were obtained mostly from County and State officials. Comparisons were also made with the State Engineers Office which collected similar data. The figures given by the Weather Bureau relate to the Sacramento and lower San Joaquin Valleys, and include losses occasioned by stream flow only.

For the Sacramento and Lower San Joaquin Drainage Areas:

Estimated total property damage of all kinds caused by stream flow ¹	\$6, 731, 054
Estimated value of property saved by warnings.....	\$2, 060, 000
Total acreage of agricultural lands flooded (approximately).....	508, 798

¹ Not included are general storm damages, such as from wind, and earth slides and erosion in the mountains. The State of California, Public Works Department, estimates a loss of \$12,041,600, covering all losses from the storm for the entire state.

Acknowledgment is made of the valuable assistance given by all of the observers who stuck to their posts and

made rainfall and river-gage readings frequently during day and night; of the aid given by United States engineers who, particularly in one case, assigned two of their employees at Marysville to help our river observer during the emergency, the engineers, in day and night shifts taking hourly readings and answering hundreds of

telephone calls as to the behavior of the river; also of the valuable cooperation of the telephone and telegraph companies, the radio and the press, in distributing warnings.

In this connection it should be stated that the Red Cross and other agencies promptly provided all necessary relief and rescue facilities throughout the Valley.

NOTES AND REVIEWS

O. HOELPER. *Atmosphärische Trübungs- und Wasserdampfbestimmungen nach Filtermessungen der Sonnenstrahlung*. Reichsamt für Wetterdienst, Wiss. Abh. 5, n. 10, 49 pp., Berlin, 1939

Filter measurements of solar radiation, and their reduction by Ångström's method to obtain dust turbidity and precipitable water in the atmosphere, are here published for Potsdam, Schomberg, Davos, and Zugspitze. Data for Aachen have already appeared (*Deutsches Met. Jahrb. Aachen für 1933*, 55-62, 1935).

The practical difficulties in the way of getting sufficiently accurate solar radiation measurements seem to have been to a large degree responsible for the limited use of this theoretically very simple method for getting the total moisture content of the atmosphere above any station. These difficulties are here reviewed. It is pointed out that concurrent readings from several stations all within the same air mass have helped to remove some of the errors; conversely, agreement in the results of independent and well-separated simultaneous observations has emphasized the uniformity in some of the characteristics of an extended air mass.

Theoretical difficulties of the Ångström method, such as the assumption of a mean effective size of scattering particle, and the anomalous behavior of scatter in the UV region, are claimed to be of little consequence in view of the rough nature of the required characterizations of the atmosphere.

Hoelper sets up a transformation table to put the results of observations at Blue Hill and Washington (published in the *MONTHLY WEATHER REVIEW*, 1933-37) in terms of the European reductions. Much of the disparity in the Blue Hill results is supposed by Hoelper, as by Kimball, to be probably traceable to improper filter transmission factors. It may be mentioned here that in September 1938 it was discovered at Blue Hill that both the OG-I and the RG-2 Jena glass filters, continually exposed there in clear or partly cloudy weather during the previous 5 years, had steadily deteriorated by crystallization at and just below the glass surfaces. Subsequent development of an empirical method for estimating the curve of transmission decrease of these filters with advancing time made possible the reevaluation of Blue Hill turbidity measurements now under way.

Hoelper discusses a new method for correcting the reductions to turbidity and water-vapor content on non-normal days. It was found that observations indicating extremely high or low turbidity did not yield true values of precipitable water by the usual reductions. By the use of simultaneous airplane observations of atmospheric moisture content, a correction curve may be developed for any station, based on the differences between the precipitable water found by the two methods, plotted against the differences in the corresponding turbidity coefficient obtained from two spectral regions. This curve permits adjustment of the quantity of precipitable water obtained through radiation measurements and use of the corrected quantity to obtain a truer value of the turbidity. A few

successive approximations suffice for even the most extreme conditions. It is felt by Hoelper that this method provides, where necessary, at least a partial correction for the Ångström approximation in assuming a mean effective size of scattering particle.

Another subject discussed by the author is the frequently observed inconsistency between the surface vapor pressure and the precipitable water as obtained by the filter method. The mean relation between the two does not conform to theory, for a nonlinearity appears when they are plotted in a scatter diagram. This is similar to the nonlinearity found in recent spectrographic measures of water-vapor absorption when plotted against the corresponding surface vapor pressure (Herzing, *Gerl. Beitr.* 49, 71, 1937). It seems to be accounted for by considering Fowle's absorption F , due to water vapor, not as a mean function of $W \cdot m$ (where m is the optical air mass) but as a family of curves, each of constant m . It then appears that for large m , F falls below the mean F for all W ; and for small m , F lies above the mean F . Thus an observed F in winter (with relatively large m) should yield a much higher value of $W \cdot m$ than the same F in summer. It is of course understood that the preceding correction only partially meets the difficulties inherent in approximating the total precipitable water from the surface vapor pressure.

Perhaps the outstanding contribution of this paper is in calling attention to the importance of essentially simultaneous solar observations. Confirmation of the results of one set of observations by the results of an entirely independent set is one of the fundamental "controls" in scientific research. For estimating the effects of the especially numerous known and unknown sources of error afflicting solar radiation measurements, particular emphasis on concurrent observations offers one of the most important possibilities.—*Edmund Schulman*.

W. W. SPANGENBERG. *Strahlungs—Klimatologische Betrachtungen*. Aus d. Archiv d. deutschen Seewarte, 58, n. 8, 32 pp., 1938.

The author compares the mean monthly values of transmission, turbidity, and maximum intensity of both the total and the red-infrared radiation at eight stations of varying elevation in central Europe. The differences are discussed in terms of variations of the climatic elements in place and time.

Of especial interest is the discussion of intensity fluctuations of a few minutes duration. In absolute value as well as in percent, these fluctuations are shown to vary inversely with the solar elevation, for the total as well as for the less fluctuating red radiation. Variations up to 30 percent for large air masses are found. Wind, in combination with stratified or otherwise heterogeneous distribution of dust and other scattering and absorbing particles, is held to be the causative agent. The effect of the lowest layers of the atmosphere in introducing long-period (month-to-month) variations in radiation is emphasized; at relatively high solar elevations these variations apparently smooth out.—*Edmund Schulman*.